3-D Attenuation Structure beneath the Kanto District, JAPAN

Ryoichi Nakamura
Tokyo Electric Power Services Co. ,Ltd
Kenji Satake, Shinji Toda
National Institute of Advanced Industrial Science and Technology
Tomiichi Uetake
The Tokyo Electric Power Company Inc.
Shin'ichiro Kamiya
Japan Agency for Marine-Earth Science and Technology

Abstruct. Here we report our estimate of 3-D attenuation structure by dense seismic network. We obtained the Qs structure at 5Hz in the Kanto area using strong motion records of the K-NET and KiK-net of National Research Institute for Earth Science and Disaster Prevention (NIED). We found several low Qs zones, most of which correspond to the volcanic front. A significant NW-SE trend low-Qs zone however lies under the non-volcanic Kanto area. This low-Qs zone exists about 36.0deg N at 20-60km. In the 3-D velocity model [Kamiya and Kobayashi, 2000], low-Vp and low-Vs with NW- SE trend and high Poisson's ratio are found at 36.0deg N at the depth of 40 km. The low-Qs zone found in this study corresponds to this zone, and indicate wedge just above the subducting PHS plate..

Introduction

Subsurface structure, both seismic velocity and attenuation, beneath the Kanto region is complex. The Pacific (PAC) plate subducts beneath Tokyo from the east and the Philippine Sea (PHS) plate subduct from southwest. Because of this complexity, three-dimensional (3D) velocity and attenuation structure should be examined and may be used for both reappraisal of historical earthquake sources and prediction of intensity distributions from future large earthquakes. 3-D attenuation structure for Japanese Islands was estimated from seismic intensity distribution (Hashida, 1989). More detailed attenuation structure beneath the Tohoku region (Nakamura and Uetake, 2004), from a large number of strong-motion records, show that high Qs in the Pacific plate and very low Qs in volcanic zones. Here we report our estimate of 3-D attenuation structure estimated from dense seismic network. We obtained the Qs structure at 5Hz in the Kanto area using large number of strong motion records.

Data and Methods

In the present study, we determine three dimensional attenuation (3-D Qs) structure beneath the Kanto district, central Japan by a tomographic method.

The data used in this study are the K-NET and the KiK-net strong motion records opened by the NIED. Number of the K-NET and the KiK-net are now 1,035 and 675 stations respectively. From these data, we could used 39,948 observational data during the period from 1996-2004. For neglecting site surface effects on seismic ground motion, we classified the stations of the K-NET and the KiK-net respectively into 4 groups based on the ground conditions by the predominant period calculated using logging data. The distribution of the earthquakes and the observational station were shown in **Figure . 1**. The density of the observational stations is very high.

The formulation of inversion for estimating 3-D Qs structure we used is mainly based on Hashida and Shimazaki [1984] and added it unknown parameter of site amplification for the 4 groups [Nakamura and Uetake, 2002] as follows,

$$\alpha_{IJ} = Sa_J \cdot G \cdot g_L \cdot \exp\left\{-\pi \cdot f \cdot \sum \left(T_K / Q_K\right)\right\} ,$$

where α_{IJ} is the ground acceleration spectrum, Sa_J is the source acceleration spectrum, G is the geometrical spreading factor, g_L is the site ground amplification factor of l-th group, Q_K is the quality factor of the k-th block, and T_K is the time spent in block k. The whole study region is divided into rectangular blocks and the attenuation is assumed to be constant in each of them and the Σ is made over all blocks penetrated by the ray from j-th earthquake to i-th station. We calculated Fourier spectrum α_{IJ} for 5Hz by taking geometric mean in range of 4-6Hz,

We use iterative inversion. For iteration, we taking minimal residuals of ground acceleration between the observed ground acceleration spectrum α^o_{IJ} and the calculated spectrum α^c_{IJ} obtained by initial source acceleration spectrum, site amplification factor and Qs-value. The initial source acceleration spectrum is given using function by Boore [1983] and seismic moment converted from magnitude. The initial value of the site amplification factor and the quality factor are given as g_{OL} =3 and Q_{OK} =$100f^{1.0}$, respectively. For 3-D inversion we use the ARTB method following Herman [1980].

For the model space, we take the longitude and latitude range of 138-142degE and 34-38degN respectively. The size of divided rectangular block is taken as 0.2deg * 0.2deg * 20km. We adopt the S-wave velocity model proposed by Ichikawa and Mochizuki [1971].

The number of blocks hit by rays is 1460 and the total number of the model parameter is 3724. We use the results after the global 250th iteration of ARTB. Here, the method contains no constraint on the value of the quality factor. Therefore we simply substituted any negative value with a large positive Qs value once in fifty global iterations.

Results

Figure . 2 shows the obtained attenuation structures at depth range of 20-40km and 40-60km in this study. The upper boundary of the Philippine sea plate is also shown as gray dotted line. **Figure . 3** shows the checkerboard resolution analysis test at the same depth. In this test, high-Qs(400) and low-Qs(100) blocks are assigned to 3-

D grid alternately. The ray paths of this test are same as the inversion in this study. From these results, we can designate some characteristics the attenuation structure beneath the Kanto district as follows.

At 20km-40km depth, Low Qs zones were obtained along active volcanoes (solid triangles in Figures.), and from the southern part of Ibaragi prefecture to the northern part of Chiba prefecture in spite of non-volcano. At 40-60km, it is similar to 20-40km depth, but the Low-Qs zone of Ibaragi and Chiba prefecture spread northern and western area.

Figure . 3 shows the cross section of A-A' in **Figure . 2**. The Philippine sea plate (PHS) slab shows High-Qs. Strong Low-Qs zone from 37 deg. to38 deg. is corresponds to active volcanoes area (the volcanic front). The Low-Qs zone at depth 30-60km from 35.5 deg. to 36 deg. is of Ibaraki and Chiba Low-Qs zone.

Discussion and Conclusions

First, we calculate seismic ground motion prediction using obtained Qs structure of the 23 July 2005 earthquake (M6 and Depth=73km), which is not concluded in the inversion data set. Deep focus earthquakes often cause abnormal seismic intensity distributions. **Figure. 4** shows comparison between the observation and the calculation ground motion of acceleration Fourier spectrum at 5Hz. High intensity area of both tend to distribute on the west side of epicenter. This phenomena can be explained by existence of the Low-Qs zone at the northern part of Ibaragi prefecture to the north part of Chiba prefecture and the High-Qs of the PHS slab (Ishida, 1992).

Next, we will discuss about origin of these Qs structures.

Nakamura and Uetake [2004] also obtained 3-D Qs structure beneath the Tohoku district using same method. This result shows that the Low-Qs zone good agree with High-Vp/Vs zone obtained by Nakajima et al.[2001]. High-Vp/Vs correspond to High Poisson's ratio. Nakajima et al.[2001] described that causes of High-Vp/Vs are H_2O and/or partial melted materials. Also, serpentine material can show High-Vp/Vs [Christensen, 1996]. But, the High-Vp/Vs and the Low-Qs zones near volcanoes suggest high temperature and existence of fluid materials because of high geothermal temperature in active volcanic area.

Otherwise, as mentioned above, we obtained the Low-Qs zone from the southern part of Ibaragi prefecture to the northern part of Chiba prefecture in spite of no volcano. This agree with the region of High-Poisson's ratio (High-Vp/Vs) obtained by Kamiya and Kobayashi[2000] using the arrival time data of from the catalog by the National Research Institute for Earthquake Science and Disaster Prevention (NIED). Kamiya and Kobayashi[2000] shown two alternative explanations to this phenomenon as hydrated mantle peridotite and partial melt of the wedge mantle, and they concluded that the former is preferable by the reason of pressure-temperature equilibrium relation of serpentinized peridotite. Sekiguchi[2001] also obtained High-Poisson's ratio at same region using NIED micro earthquake observational net data. Seno et al.[2001] described that there is a double seismic zone, and this can be explained by the dehydration of the serpentinized wedge corner.

Although it is difficult to resolve the problem of cause of the Low-Qs zone from only 3-D Qs structure, serpentine and/or dehydrated materials possibly can explain Low-Qs structure.

Otherwise, 3-D velocity and attenuation structure affect strongly seismic ground motion. McNeill et al. [2004] examine the effect of forearc mantle serpentinization on ground motions by numerical simulations only considering velocity inhomogenuity and reported that ground motions are dramatically influenced in the case of intraslab events that underlie serpentinized fore arc mantle. In our study, the significant low-Qs zone found from the southern part of Ibaragi prefecture to the northern part of Chiba prefecture in spite of non-volcano. and indicate wedge just above the subducting PHS plate. Such 3-D structure would play an important role to evaluate seismic intensity from earthquakes in the region.

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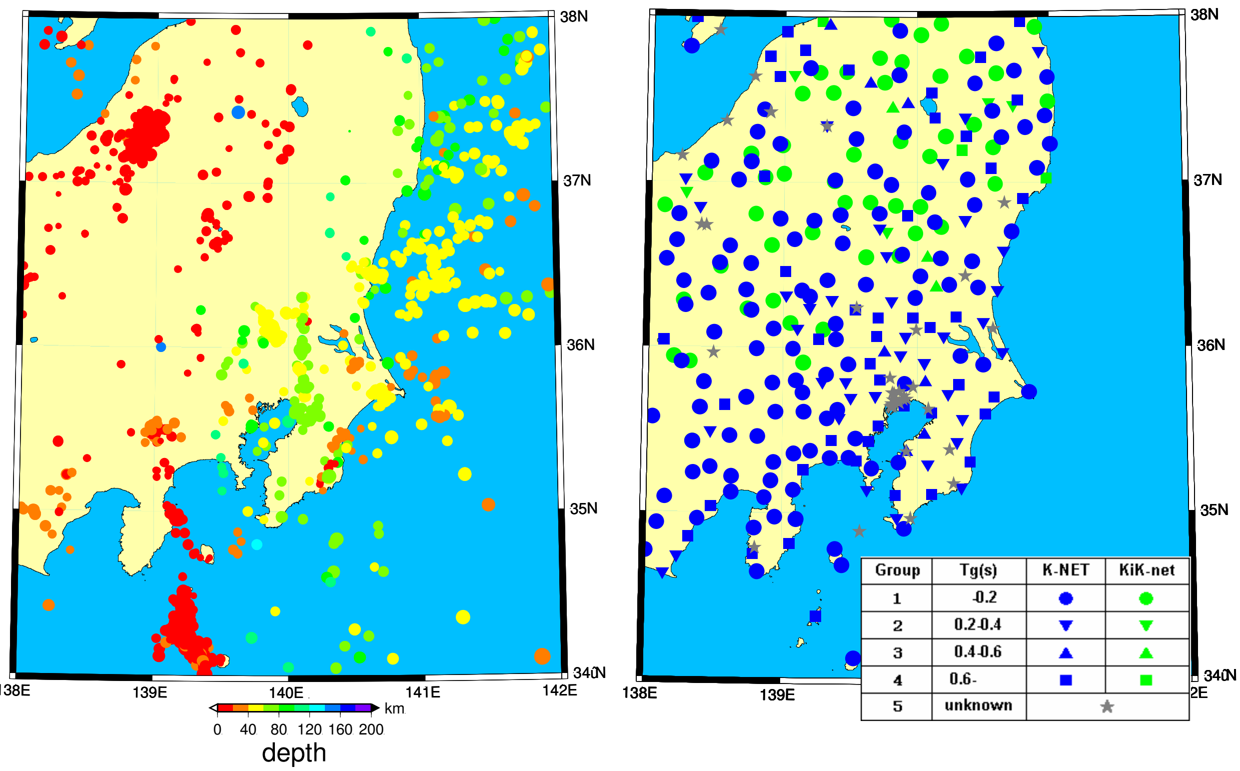

Figure 1. Distributions of epicenter (left) and stations(right) used in this study. Green and blue symbols of station denote KiK-net and K-NET stations respectively.

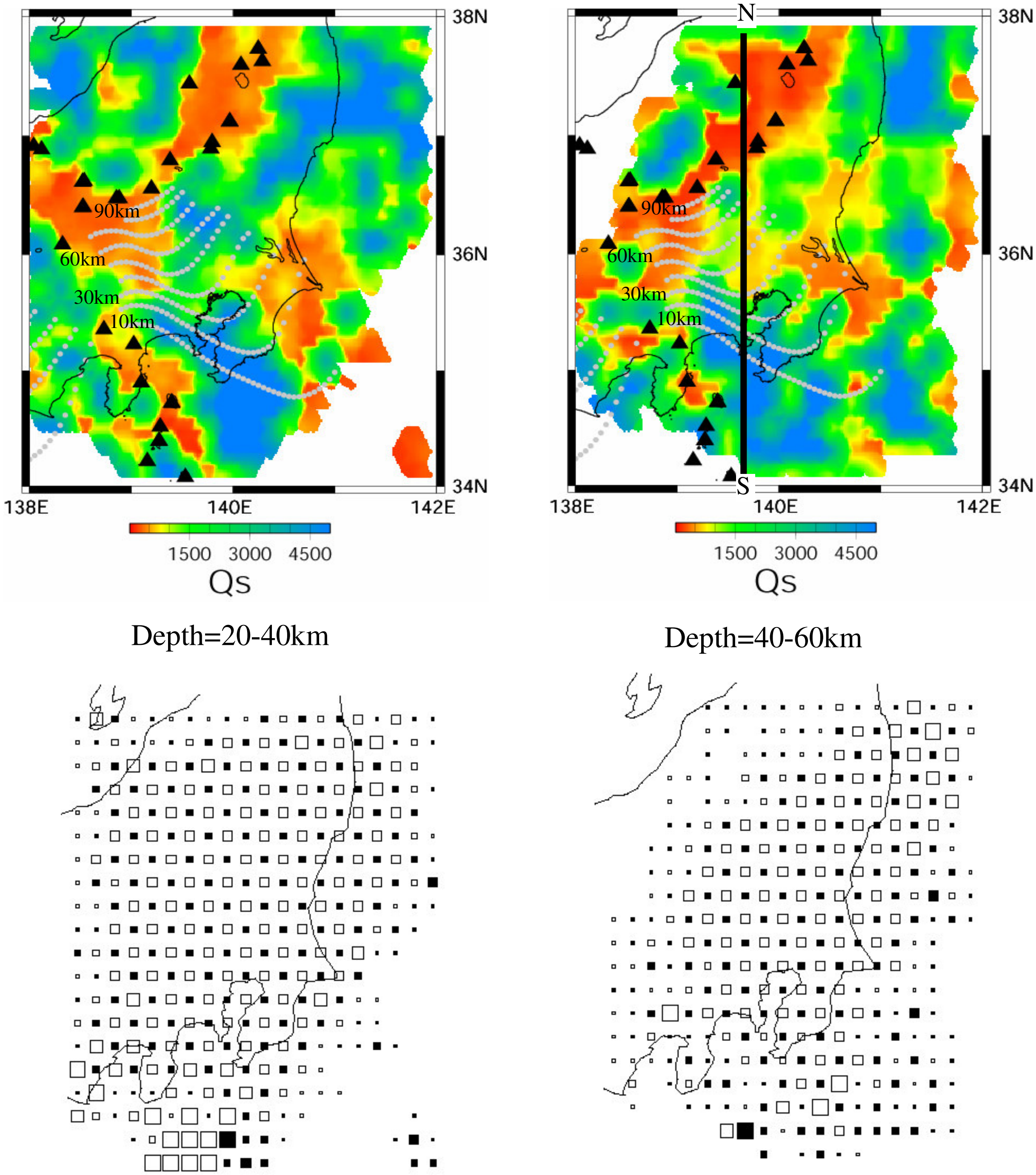

Figure 2. Estimated Qs distribution (top) and results of checkerboard resolutions(bottom) at 20-40km (left) and 40-60km (right) in depth beneath the Kanto district. Thick solid line indicates the location of the cross section shown in Figure 3. Solid triangles denotes the active volcanoes and gray dotted line denote the upper boundary of the Philippine sea plate after Ishida[1992].

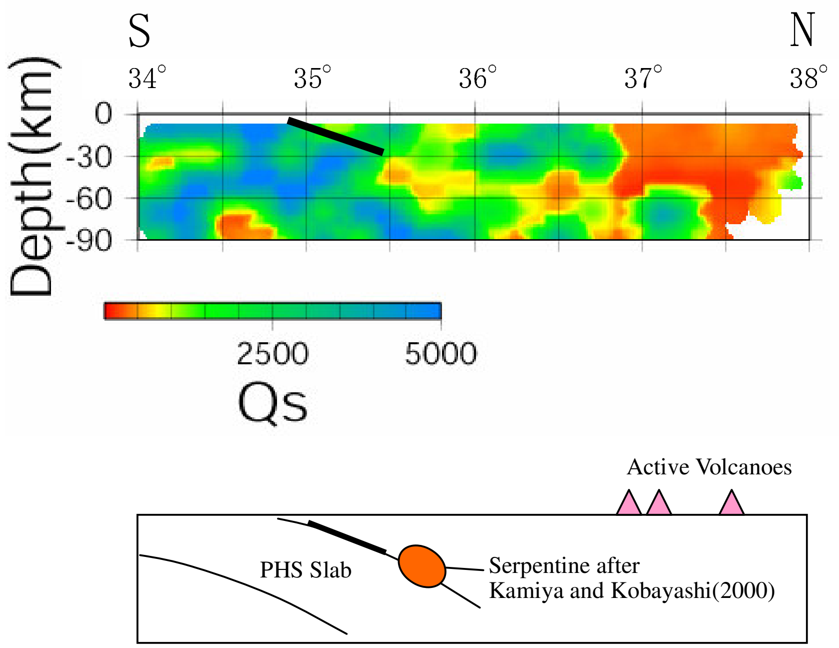

Figure 3. Vertical profile of estimated Qs structure (top) at N-S line shown in figure 2. A fault model of the 1923 Kanto earthquake estimated by Matsu'ura and Iwasaki[1983] is shown in this figure as thick line as well as Kamiya and Kobayashi[2000]. Schematic illustration (bottom) shows the Philippine sea slab (PHS) and serpentinized area proposed by Kamiya and Kobayashi[2000]

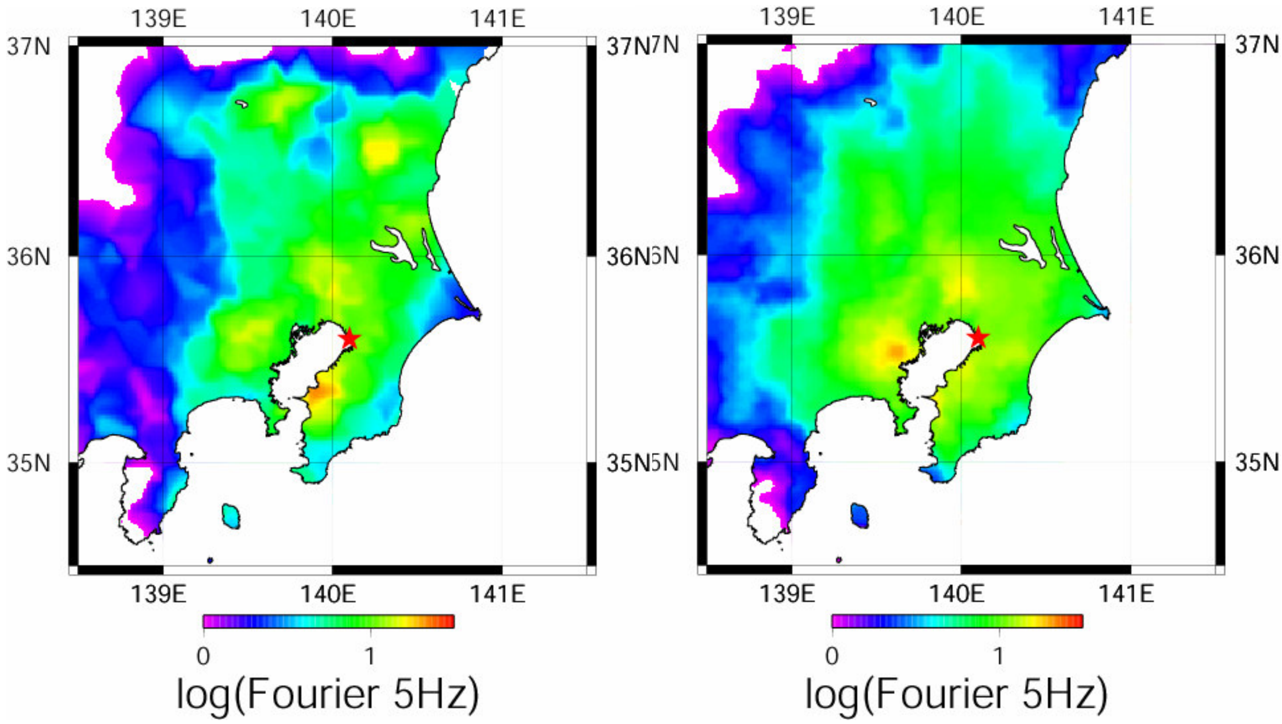

Figure. 4 Comparison between the observation (left) and the calculation (right) ground motion of acceleration Fourier spectrum at 5Hz of the 23 July 2005 earthquake (M6 and Depth=73km). High intensity area of both tend to distribute on the west side of epicenter.